

The Integration of Infrared [environmental Simulation techniques into a Test Routine at JPL

Georg Siebes

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

Extended Abstract

The costliness of conventional thermal vacuum testing is well known and has been the driving force behind efforts to develop a cost effective alternative. In recent years infrared simulation techniques have proven to be a viable approach. Tungsten filament lamps that are used can produce flux levels that are equivalent to several solar constants. Depending on the configurational arrangement of these lamps highly uniform flux distributions can be achieved over large areas, a feature otherwise found only in large solar simulators. Operation of solar simulators is complex and expensive; not every testing facility is equipped with them. Alternatively, infrared simulation may enable a test program that otherwise would have to be carried out at remote facilities, with all their associated logistical problems.

IR simulation has unique characteristics that need to be taken into account when a test configuration is planned. First, it is important to understand that an IR simulation is not a substitute for a solar simulation. If the effect of a collimated beam or other solar properties such as optical surface properties are key parameters, then IR simulation is inadequate. If solar simulation is considered because of achievable flux levels or because of requirements for large illuminated areas, e.g., solar panels, then IR simulation is the preferred alternative.

Second, the spectral distribution of IR lamps is a function of temperature which in turn is related to the applied voltage. Peak energy output at rated voltage occurs at $1.1\ \mu\text{m}$ or larger wavelength for voltages less than the rated voltage. This compares to $0.45\ \mu\text{m}$ for solar radiation. The actual spectral distribution during a test phase can only be estimated a priori. If test requirements are insensitive to spectral properties, e.g., a requirement to soak at a selected temperature, then IR heating can be directly applied. For other tests, like the frequently performed thermal balance test, the knowledge of absorbed energy is of paramount importance to subsequent data correlation. Thermal control surfaces are often spectrally selective, e.g., low solar absorptance and high IR emittance for a radiator. If the spectral distribution shifts during the test and cannot easily be determined prior to the test, then the resulting absorbed fluxes need to be measured directly during the test. This led to the development of simple calorimeters that are used to monitor absorbed fluxes and to feed back signals to the associated IR simulation controls.

The calorimeter is a thermally isolated sample disk that exhibits the same optical properties as the surface that is being flux-controlled. Because the calorimeter has optical properties identical to the test surface, it absorbs incident flux just as the surface that it represents. A pre-test calibration yields absorbed flux as a function of housing and sample disk temperature. During the test the calorimeter is placed in front of the surface of interest, providing it with a similar view. The calorimeter temperatures are converted to flux in real time and used for control of the IR heat source,

In all tests performed at JPL, the IR heat source was constructed from a combination of quartz envelope/tungsten filament lamps and reflectors. The arrangement of these elements into lamp arrays, as well as the geometric relation between the lamp and the reflector, determines the spatial distribution of the emitted energy. The resulting lamp array geometry is complex and while it is possible to analytically assess the resulting flux distribution, it is a very cumbersome effort. Therefore, a technique was developed at JPL to use an existing imaging radiometer to rapidly measure the flux distribution of large areas and, ultimately, to provide lamp arrays that provide flux uniformity of 10% or better.

The last element of JPL's IR simulation technique is computer control. When flight hardware is tested, safety is of utmost importance. Driven by requirements, the amounts of power installed during past tests at JPL has ranged from 5KW to 350KW, in most cases enough to potentially do irreversible damage to the test article. Real time closed-loop control is therefore mandatory. The control software integrates many checks of the test and control hardware into a real time status monitor and can react almost instantly to alarm conditions,

The integration of IR heat sources, calorimeters and flux sensors in a computer controlled test environment has evolved for some years at JPL. The first test involving lamp arrays was the Magellan solar panel test in 1988. The M1 S (Microwave Imb Sounder) instrument followed in 1989. The TOPEX (Ocean Topography [experiment] solar panel qualification, consisting of 250 temperature cycles, and the subsequent acceptance test of four flight panels, was concluded in 1990. The test software was extensively reworked and throughout 1993 seven NSCAT (NASA Scatterometer) antennas were qualified and flight acceptance tested followed by a system level thermal balance test and calibration which was concluded in August 1993.

Today, JPL has an established IR simulation technique that has proven to be reliable and cost effective in numerous tests. Figure 1 gives an example of temperature cycling. It is evident that temperature cycles are very repeatable due to precise flux control. As a result the test duration was minimized and the test time line became much more predictable.

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